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Effect of Deposition Temperature on Optical and Crystallographic Properties of CsI Thick Films Deposited using Spray Pyrolysis

Abstract- *A deposited layer of CsI has been prepared at different substrate temperatures using spray pyrolysis technique. The X Ray diffraction of CsI films reveals special pattern peaks (110), (200), (211), (220), (310) and (321). From transmission spectra we calculated the energy gap of CsI films which increase with increasing deposition temperature for direct transition is estimated.*

Keywords: *X-ray diffraction, Crystallite size, Grain size. Cesium iodide CsI*

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1.Introduction

owing to its highest quantum efficiency (QE) with better stability under short exposure to air [1].Cesium iodide (CsI) is a good photo converter material in photocathodes designity which used in many UV-detecting devices [2, 3],. CsI films are also used to enhance the field emission (FE) sources which have potential applications including display devices [4], X-ray tubes [5], charged particle accelerators [6] and high power microwave devices [7]. Due to the importance of CsI photocathodes, several thin film preparation methods were used in deposition process, such as thermal evaporation [8, 9]. Ion beam sputtering technique [10], e-gun evaporation technique [11], spray pyrolysis technique [12], pulsed laser deposition technique [8, 13]

2-Experimental part

I.Substrate preparation

The CsI are deposition on borosilicate glass slide with dimension (1.5x1.5cm),that are first washed in Distilled Water for impurities removal, after that it rinsing in chromatic acid(for two-day), followed by washing in deionizer water, at last step, the impurities removed using distilled water for 15min in ultrasonic agitation and dried.

II. Deposition of the CsI films

Polycrystalline film CsI sample that studied are deposited by spray pyrolysis method. 1.2gm of 99%puriuty CsI powder from (DEHANE radial deform) is dissolved in 100ml ionized water at 30^{o}C using magnetic stirrer for 30min. After that we put the final solution of CsI in glass tube of spray system.We put the deposition substrates on the heater at distance (20 cm) away from the head of nosily spraying, then rising of substrate temperature to a deposition temperature. The deposition proses like spraying pulses at time of (4sec) for each pulse with stopping period between each spraying pulse of (26sec) at total spraying time of (60min). CsI films deposited at deposition temperatures range (150, 200, 250, 300^{o}C) as in (fig-1).

3-Theory

I.Optical Measurements:

The transmission spectra for all CsI films were taken in the spectral range of (200 – 900) nm using Phenix-2000 uv-vis spectrophotometer. Absorption coefficient (α) calculated by the following formula [14].

$$\alpha = \frac{1}{d} \ln \frac{1}{T} \qquad \ldots(1)$$

Where: **d** represent Thickness of thin films and **T** represent Transmission, **α** absorption coefficient and Optical band gap **Eg** is given by [15].

$$\alpha h\nu = A(h\nu - Eg)^{n} \qquad \ldots (2)$$

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Where : **A** represent constant dependent on transition probability, **h** represent plank's constant, **υ** is Frequency of incident Photon, E_g is energy gap of material and **n** have different value depend on property of Absorption method. Plot of $(\alpha h\upsilon)^2$ ve. hυ gives best results, using extrapolate liner part down to $\alpha = 0$, the value of E_g could be determine. The thickness is the single most significant film parameters.

II. Thickness measurements

Thickness of layer is larger than 1µm so we measured films thickness using weight process by sensitive electrical balance of metler AE-160, with preciseness achieve 10^{-4}gm. Mathematical equation use to determine the thickness is [14].

$$\textbf{Thickness} = \Delta m / P_f \, . \, A_f \quad \ldots(3)$$

Δm: deposition film weight equivalent to variation between weight of slide after and before deposition route.

P_f: density of film.

A_f: film area.

III Structure measurement

Spectrum of diffraction of CsI films are acquired by 2Θ in the range (20-60) using Cu-Kα (Philips-PW 1840) that include following features: CuKα of (1.540A) wavelength and scanning speed 3 degree/min.

a. Grain size (D)

From the X-ray spectrum we can determined the grain size of the films using (Scherer relation)[16] **.**

$$D = \frac{0.9\lambda}{\beta \cos\vartheta} \quad \ldots(4)$$

Where: β is Full Width at Half Maximum of X-RD peaks appear at the diffraction angle θ .

b.Dislocation density σ

From the value of grain size we can determine dislocation density [17].

$$\sigma = 1 / D^2 \quad \ldots(5)$$

c. Strain ℰ

Strain values can be calculate using formula [18]

$$\beta = \left(\frac{\lambda}{D\cos(\theta)}\right) - \varepsilon \tan\theta \quad \ldots(\%) \quad \ldots(6)$$

IV. Extinction coefficients (K)

extinction coefficients estimate from the equation [19].

$$K = \frac{\alpha\lambda}{4\pi} \quad \ldots(7)$$

4- Result and discussion

Crystallite size and strain by XRD analysis

Typical X-Ray diffracts grams of cesium iodide thin films annealed at different temperatures. prepared by spray pyrolysis technique are shown in (fig-2). Indicating that pure Cubic CsI is of polycrystalline, stoichiometric nature. Further, All films show a strong preferential orientation at 2θ = 27.5 at (110) plane and sharp peak with lattice plane corresponding to the preferred peaks for CsI crystal is: (110), (200), (211), (220), (310) and (321). at Bragg's angles 2ϑ = 38.3, 48.3, 56.49, 64.7 respectively. These peaks match with the peak positions listed for cesium iodide in ASTM, confirming the films to be of CsI. The intensity of peaks decrease with increasing deposition temperatures, according to decreasing the grain size and the defects that produce.

All of this could be attributing to increase the residual stresses that generate defects which casing deformations like dislocations in the film. We observe the peak of (110) lattice plane is most intense peaks, and has a good stability without any shift in angle (2θ = 27.5). All values of full width at half maximum (FWHM), 2θ and inter-planer spacing (d) comparing it to standard d-value taken from ASTM diffraction data file to the most intense (110) peak for various deposition temperature of thin CsI films are shown in Table 1.

from (fig -3) we see that the grains increase as the deposition temperature increases between (150 – 200) °C owing to increasing the total surface energy which could be reduce with rising deposition temperature, helping the grains to agglomerate. At the temperature increases between (250 – 300) °C according to the densification process the thickness of films reduce, where the small empty spaces or pores were filled by the grains [20], which lead to increase the dislocation density as in (fig -4), and causing decrease number of layers casing to reduce the strain in the film as in (fig -5).

(Fig -6) represented relationship of CsI films transmittance at wavelength range (200 – 800) nm. The results show increasing in transmittance values with increasing deposition temperature at wavelengths range (200 – 400nm) due to increase the absorbance of the film, then transmittance saturate at wavelength above (360nm) that means CsI films result a great transmittance value at wavelength (360nm) having more than 80% at deposition temperature (250-300) °C. Near a wavelength (360 nm) we gate A sharp increase in transmittance which indicating its crystalline nature. [20]

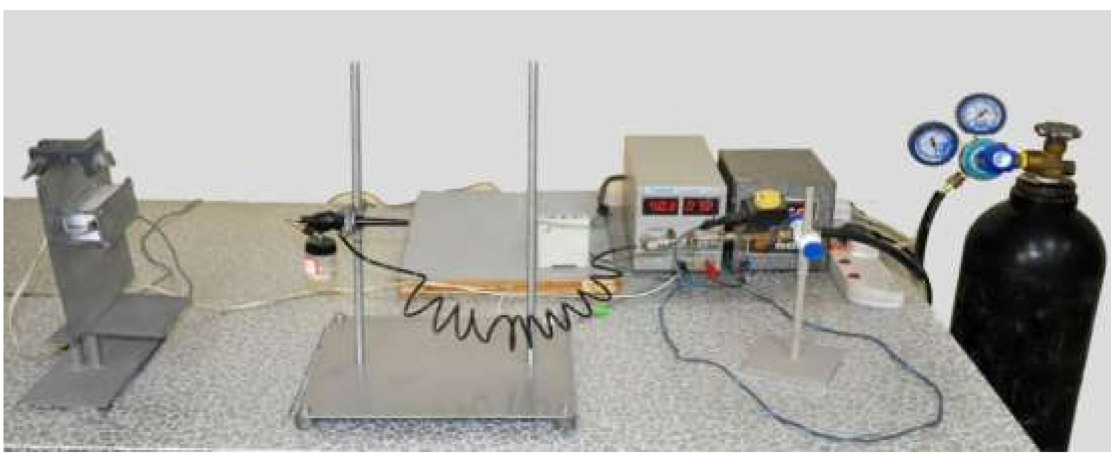
In Fig (7), that represent the relationship of CsI film absorption coefficient at wavelengths range (200 – 800nm), we can observe a decrease in absorption coefficient values with increase value of deposition temperatures at wavelength range (200 – 400nm) due to the process of doping which decrease the absorbance of the film, this may be due to the highest ionization energy of impurities (deep impurities)

Fig (8), represented the extinction coefficient of CsI films at diverse deposition temperatures. The extinction coefficients reveal the amount of energy absorbed in films, which means amount of Extinction for electromagnetic waves within material and depending on Free Electron Density and structure defect. The Extinction Coefficient of CsI films at wavelength (220-360) nm increase with increasing deposition temperature, and sharp decrease in 240nm at IR region, this may be due to decrease in the energy gap for films.

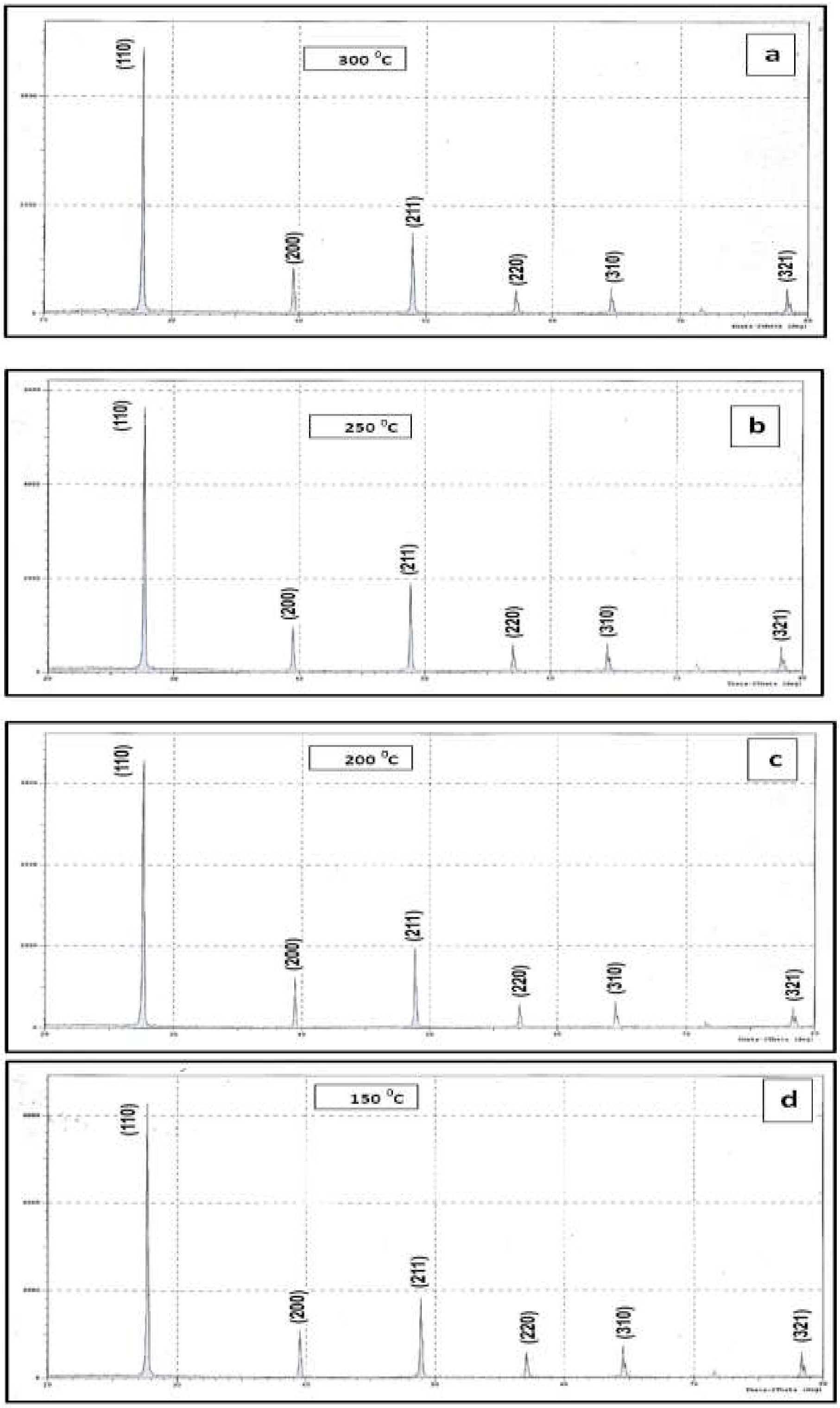
(fig-9) represent relationship between energy gaps of CsI with deposition temperatures. Increasing deposition temperature lead to increase energy gap due to the decrease in the crystallinity and the grain size of the films which lead to increase the localize states. The large crystallites of the films causes a shift of optical band gap energy.

Table 1: Structural parameters of CsI film analyses from XRD

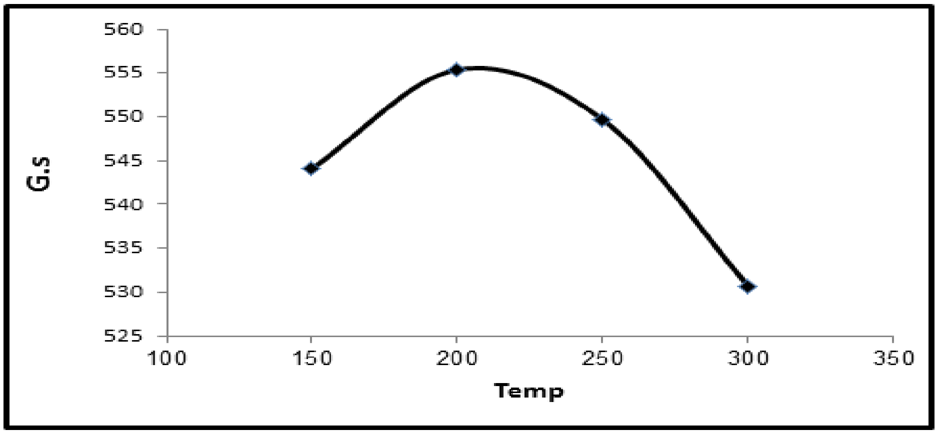
Orientation	2ϑ(deg)	D(^{o}A)Present study	D(^{o}A)ASTM value	FWHM
110	27.5	3.2109	3.23	0.00281
200	38.3	2.2749	2.284	0.00252
211	48.8	1.859	1.865	0.00272



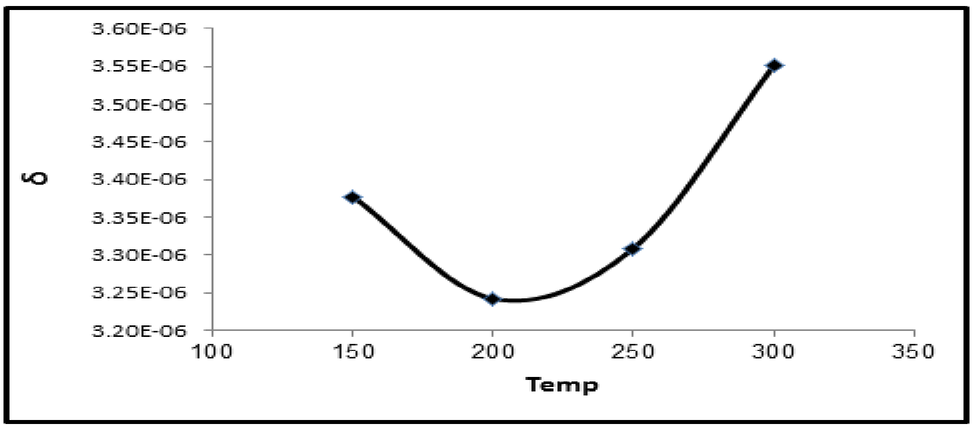
Figure(1) The system of spray pyrolysis deposition technique



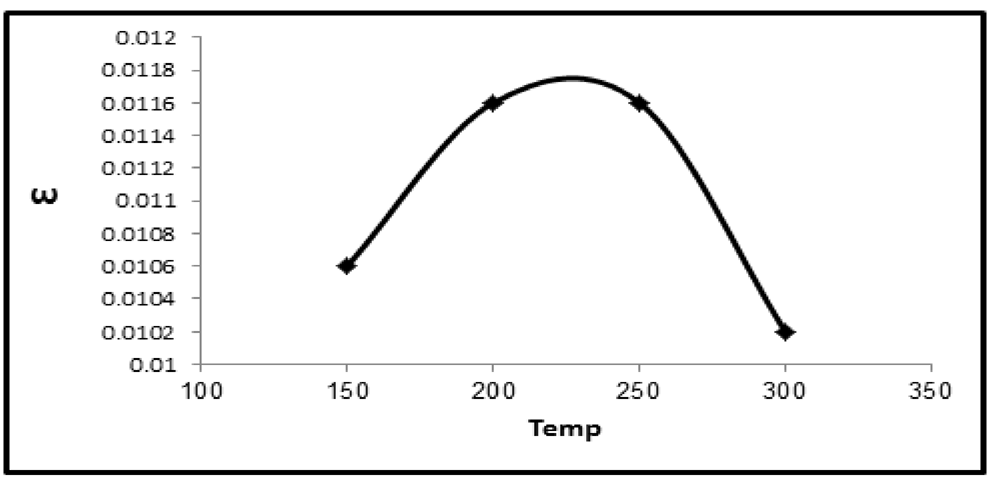
Figure(2)X-ray diffraction of CsI films, a=300 0C , b=250 0C, c=200 0C, d=150 0C



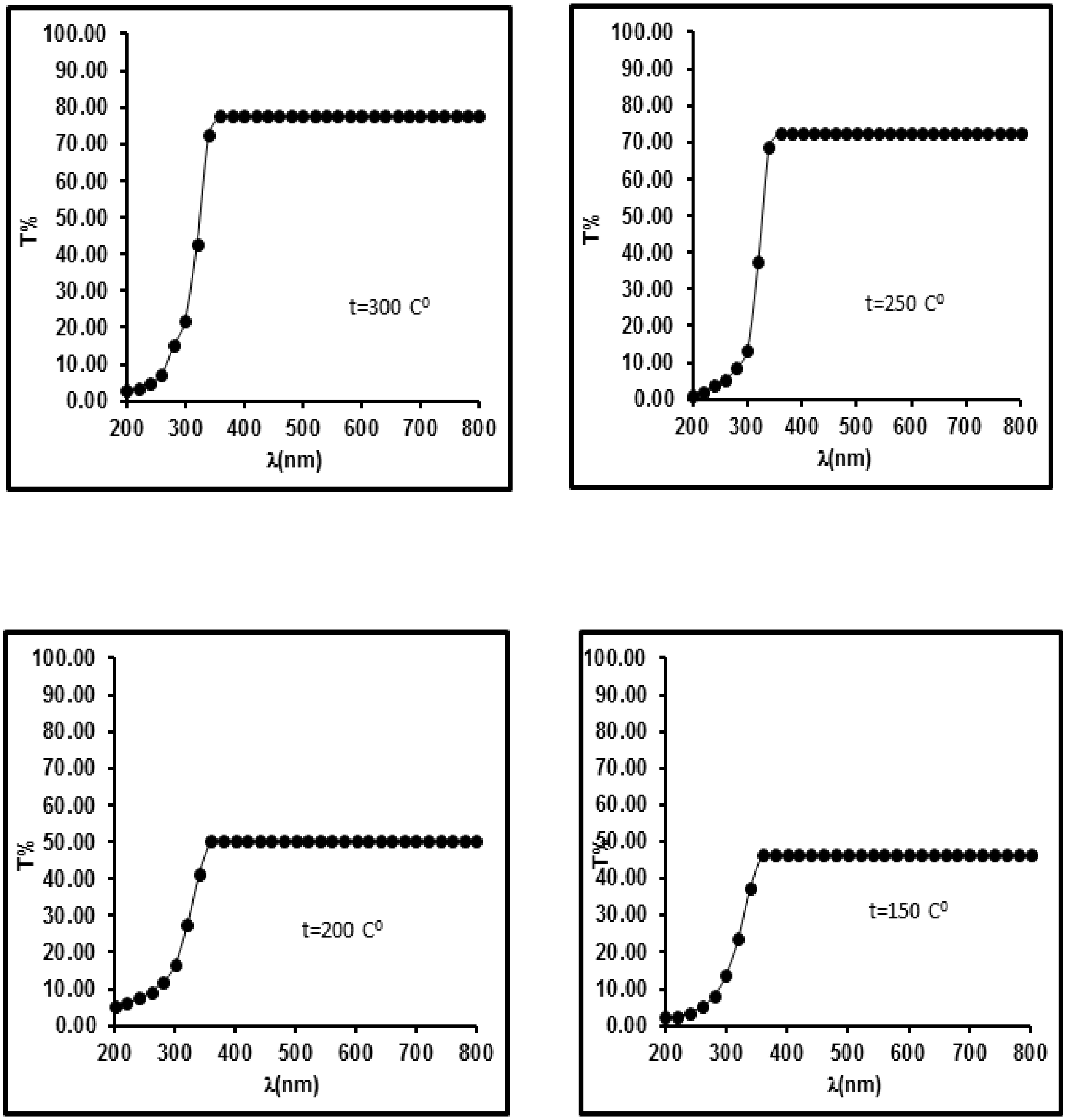
Figure(3) Grain size of CsI films



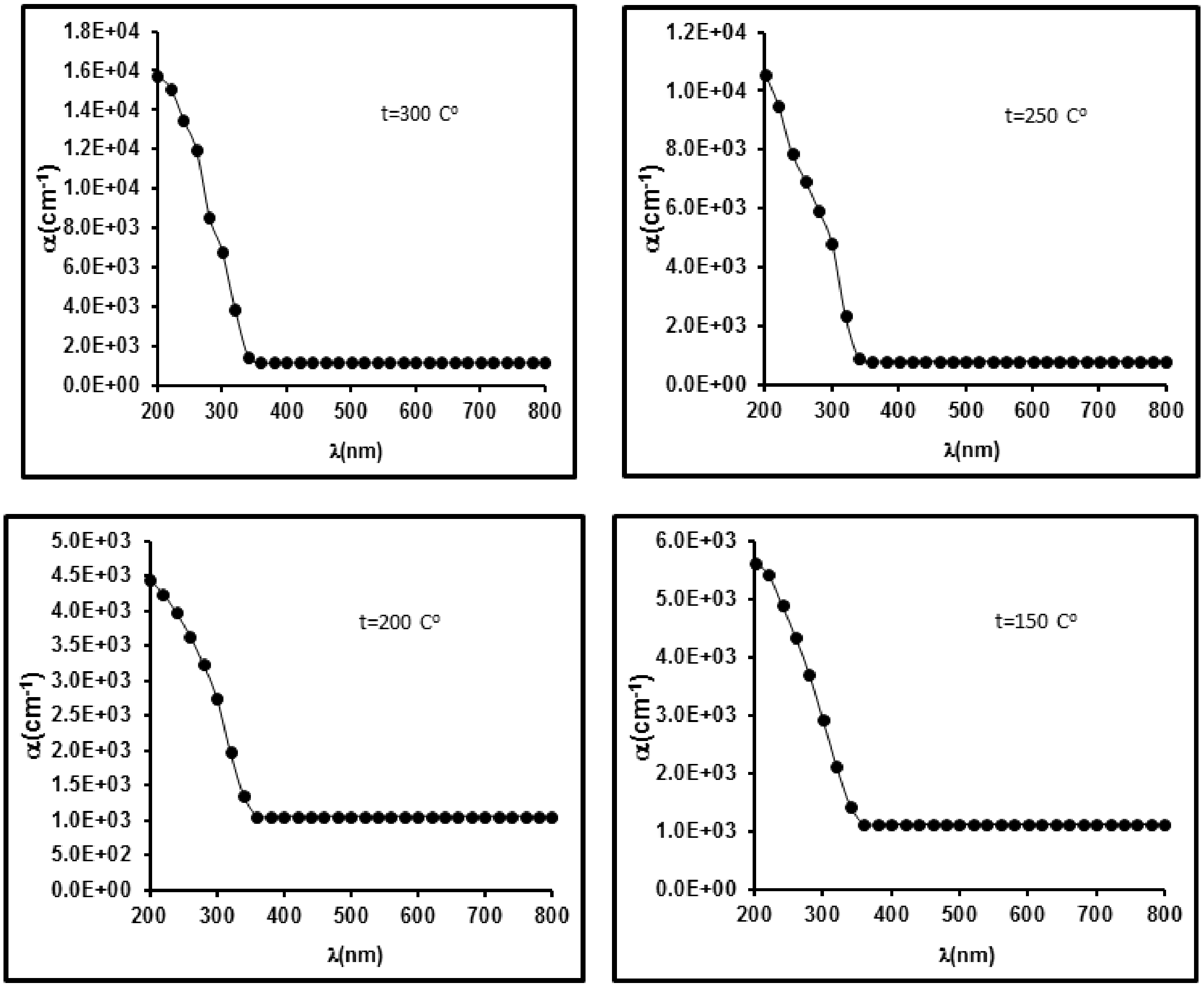
Figure(4) dislocation density of CsI films



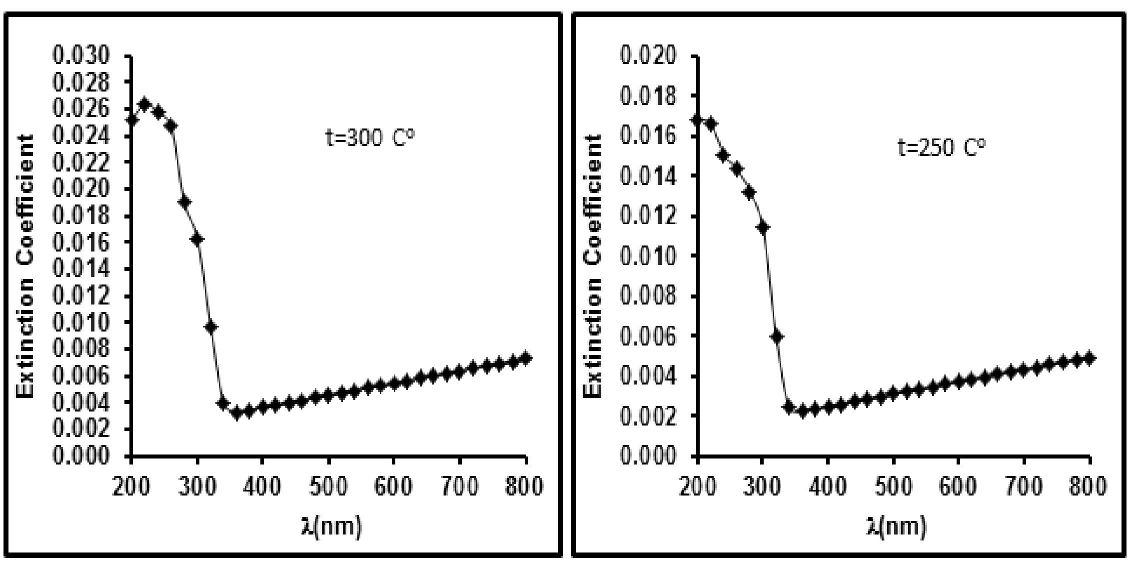
Figure(5) strain of CsI films

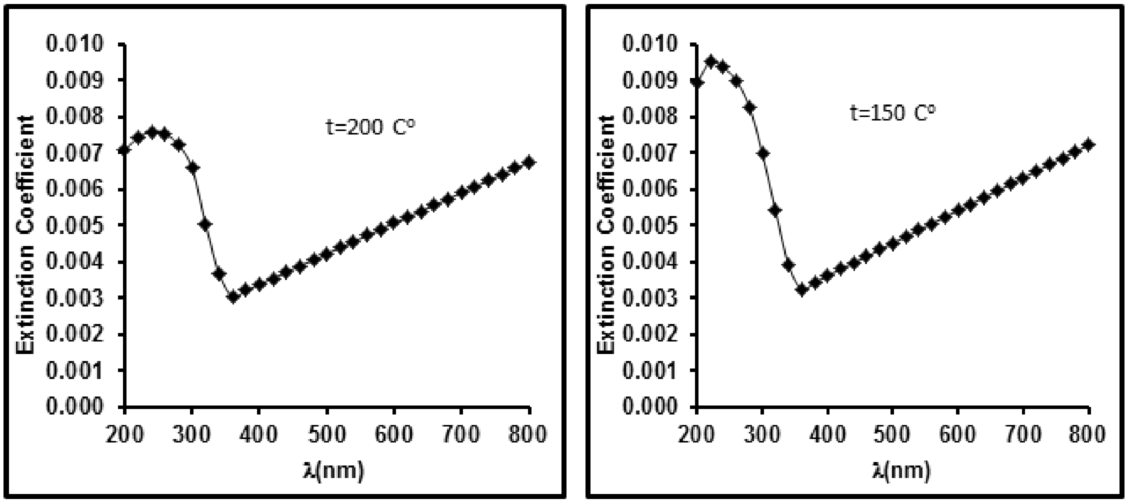


Figure(6) transmittance of CsI films

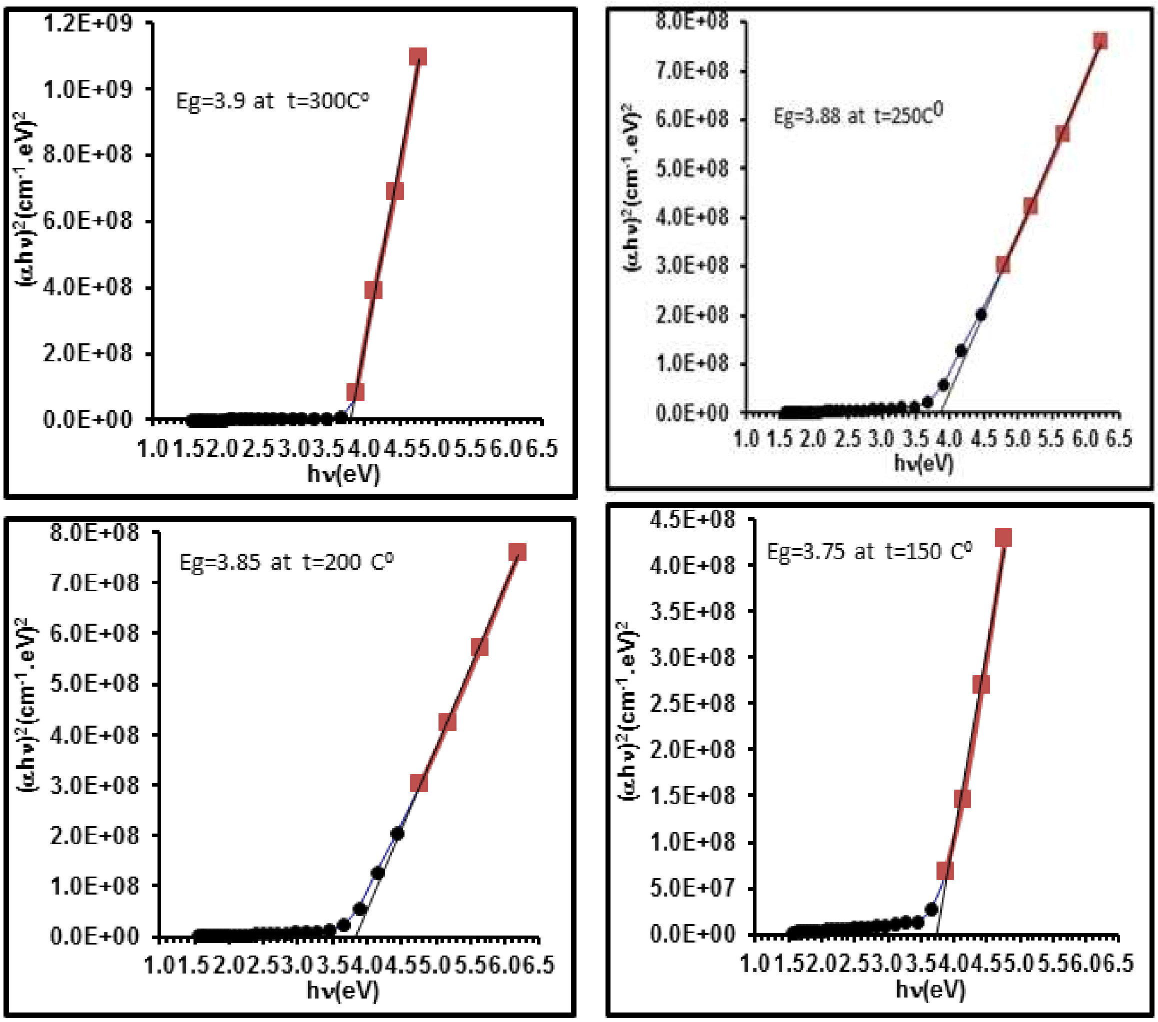


Figure(7) Absorption Coefficient of CsI films





Figure(8) extinction coefficient of CsI films



Figure(9) energy gaps of CsI films

5. Conclusion

CsI films deposited by spry pyrolysis shows a good peak orientation at (110), (200), (211), (220), (310) and (321). With increasing deposition Temperature, that includes a Cubic nature. These films show srising in transition with degreasing the Absorption Coefficient which represent direct transition. this make the films a good devise for detecting of X-ray radiation.

References

[1] A. S. Tremsin and O. H.W. Siegmund, Quantum efficiency and stability of alkali halide UV photocathodes in the presence of electric field, Nuclear Instruments and Methods A 504 (2003)

[2] A. S. Tremsin and O. H.W. Siegmund, UV Radiation Resistance and Solar Blindness of CsI and KBr Photocathodes, IEEE TRANSACTIONSON NUCLEAR SCIENCE, VOL. 48, NO. 3 JUNE 2001.

[3]A. S. Tremsin and O. H. W. Siegmund, Optical and structural properties of CsI thin film photocathode, Proc. of SPIE 59200I

[4] V. Vlashos et al., Ab initio investigation of the surface properties of dispenser B-type and scan date thermionic emission cathodes,Vacuum Electron Conference 2009 IVEC, IEEE international, pages 333-334.

[5] R. H. Bari and S. B. Patil , "Studies on spray pyrolised nanostructured SnO2 thin films for H2 gas sensing application References" ,International Letters of Chemistry, Physics and Astronomy, ISSN 2299-3843, 17(2) , PP. 125-141 , 2014.

[6] A. Jhingan and P. Sugathan., Charge particle detector development for the investigation of fusion & fusion-fission dynamics , Proceeding of DAE Symposium on nuclear physics (2012) 463.

[7] R.J. Umstattd et al., Preparation of CsI films for high power microwave devices, Proc. of SPIE 3701 (1999) 8-13.

[8] V M Brendel, S V Garnov, T F Yagafarov, L D Iskhakova and R P Ermakov. Properties of CsI, CsBr and GaAs thin films grown by pulsed laser deposition, Quantum Electronics, Volume 44, Number 9, (2014).

[9] V. Dangendorf et al. A gas-filled UV- photon detector with Csi photocathode for the detection of Xe light , Nuclear Instruments and Methods A 289 (1990) 322-324.

[10] M.A. Nitti et al. Ion- beam Sputtering deposited of CsI thin films, Appl. Phys. A 80, (2005) 1789-1791.

[11] P. Maier-Komor et al. Absolute target thicknesses for calibration of acceleration experiments.Nuclear Instruments and Methods A 362 (1995) 183-188.

[12] S.O. Klimonsky et al., Synthesis and properties of Nano crystalline CsI Inorganic materials, 2011 47 pp1033-1038.

[13] S.B. Fairchild et al. Low work function CsI coating for enhanced field emission properties J. Vac. Sci. Technol. A 29 (2011) 031402.

[14] S. M. Sze," Physics of Semiconductor Devices", Second Edition, John Wiley and Sons, New-York,(**1981**).

[15] A. J. AL-Jabiry, " Studying the Effect of Molarity on the Physical and Sensing Properties of Zinc Oxide Thin Films Prepared by Spray Pyrolysis Technique", Ph.D thesis, Applied Sciences Dept, The University of Technology, 2007.

[16] G, Zentai Partain L and Pavlyuchkova R (2007), Dark current and DQE improvements of mercuric iodide medical imagers Proc. SPIE 6510 65100 Q – 1 – 6.

[17] B.D. Cullity and S.R. S tock, "Elements of X – Ray Diffraction", Third edition, Prentice-Hall in the United States of America, 2001.

[18] G.B.williamson, R.C.Smallman, Structural, Optical constant and photoluminescence of Zno Thin Films Grown by Sol-Gel Coating, philos.Mag. 1(1956)34.

[19] K. L. Chopra,"Thin Film Phenomena" Mc Grow-Hill Book Company, New-York, (**1969**).

[20] M. P. Bole and D. S. Patil, “Effect of annealing temperature on the optical constants of zinc oxide films, "Journal of Physics and Chemistry of Solids, vol. 70, no. 2, pp. 466–471, 2009.

Author(s) biography

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The second paragraph uses the pronoun of the person (he or she) and not the author's last name. The previous publications field should be mentioned together with the current research field and the membership of any professional societies. The third paragraph begins with the authors title and last name (e.g Prof. Brimson). The authors photograph (2.5 cm height*2 cm width) is placed at the top left of the biograph